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MODELING VISUAL DETECTABILITY AND AVOIDANCE OF SCATTERABLE ANTI--ETC(U)
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Technical Memorandum 36-77

MODELING VISUAL DETECTABILITY AND AVOIDANCE OF SCATTERABLE ANTITANK MINES

Roger L. Williamson

December 1977
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U. S. ARMY HUMAN ENGINEERING LABORATORY
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When comparing the effectiveness of scatterable antitank mine systems, the countermeasure of visual detection and avoidance is a significant aspect. The probability of detecting and avoiding antitank mines emplaced on the surface of the ground varies as a function of the height of the mine, the height of vegetation on the ground, the running mode of the tank (open versus closed hatch), and tank speed. Those four parameters were combined into a geometrically derived model to produce a point estimate of the probability of detecting and avoiding a mine system. over

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20. ABSTRACT (Continued)

Additional parameters needing investigation as possibly significant additions to the model are mine color, mine camouflageability with natural debris, the presence of parachutes or mine antennas, diurnal effects, sun angle, and psychological/physiological condition of the tank crew.

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PREFACE

The need for modeling human performance, or modeling performance of a system when humans are primary controllers of system effectiveness, is becoming increasingly apparent. Evaluation of hardware alone does not completely describe the worth of a system. As attempts to incorporate human factors into evaluations of system effectiveness increase, the gap between system reliability test figures and system reliability on the battlefield should decrease. This report is an example of how a primarily human function may be formed into a quantitative model to support system assessments. Gratitude is extended to Mr. Jack Carlock of the HEL Detachment at Picatinny Arsenal for identifying sources of data and for suggesting critical factors to include in the model. Appreciation is given to Mr. Robert Carn of the Army Materiel Systems Analysis Activity for his suggestions during the development of the model.

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MODELING VISUAL DETECTABILITY AND AVOIDANCE OF SCATTERABLE ANTITANK MINES

INTRODUCTION

Current systems for emplacing antitank mines depart from past time-consuming, hand-placed burial methods by using rapid air-drop or artillery delivered scatterable mines that come to rest on the surface of the ground. Hand-buried mines are nearly impossible to detect, even at virtual zero distance from the mine, and necessitate sophisticated electronic and other techniques for detection, but modern scatterable mines are visually detectable up to 100 meters on flat, unvegetated terrain. With visual detection and subsequent mine avoidance as a possibly effective countermeasure to scatterable mine systems, a model for mine system effectiveness must include as an important factor the probability of detection and avoidance. This report provides an approach to modeling such a factor, giving specific probabilities of detection and avoidance for two different size mines under varying conditions of terrain, vegetation, distance from the tank, and tank speed.

BACKGROUND

A US Army Ballistic Research Laboratory (BRL) history of mine and countermine warfare set the perspective of the present report (7). In the First World War, the German Army introduced mines to immobilize or destroy allied tanks. Mine countermeasures were not developed. Between 1918 and 1939, the armies of the major powers emphasized antivehicular (rather than antipersonnel) devices and doctrine for mine warfare. Mines were generally hand emplaced, buried in soil and carefully camouflaged. Metallic detectors were developed by the French, German and Italian Armies.

During the Second World War, mines had a major impact on European, African, and Pacific battles for enemy and allied forces. BRL reported the following conclusion about countermeasures from a World War II study. "Although numerous methods of locating mines were tried, probing by hand was found to be the most dependable. The metallic mine detector (1945) proved satisfactory except for detection in deep snow and under water. The nonmetallic mine detector (1945) was unreliable" (11). Detectors were needed to locate buried mines not detectable by the human eye.

As shown in Table 1, BRL listed the methods of mine detection along with their relative effectiveness for Western Allies during World War II (8).

After World War II, the emphasis on buried mines continued. In 1962, the technology level for buried mine countermeasures included a long list of principles, methods, and devices as shown in Table 2.

Current scatterable mine concepts and technologies put the mine on the surface of the ground, calling for a change from countermine warfare based on the technology factor, to a reemphasis of mine countermeasures using the human factor of visual detection and avoidance. The model presented in this report takes a step in that direction.

TABLE 1

Mine Detection Methods (BRL, 1972)

Method of Detection	Relative Adjectival Rating	
	Speed	Effectiveness
1. Human Eye	Fast	Variable
2. Hand Probe	Slow	Reliable
3. Electro-Magnetic Metallic	Fast	Lacks Discrimination[a]
4. Electronic Nonmetallic	Fast	Lacks Discrimination[a]

[a]i.e., produces false positive detections.

TABLE 2

Countermine Warfare
SWRI Report [August 1962] (10)

SWRI: Investigations	SWRI: Other Methods Noted
1. Electronics	1. Field of an Electromagnet
2. Electromagnetic and Electrostatic Field and Wave Theory	2. Microwave Imaging
3. Microwaves	3. Dielectric Properties of Explosives
4. Filtering and Information Theory	4. Two-Dimensional Inverse Filter
5. Acoustics	5. Perturbance Meter
6. Vibration Phenomena	6. Microwave Seismic System Scanning Noise
7. Antenna	7. Paramagnetic Resonance
8. Radio-frequency Spectroscopy	
9. Vapor Chromatography	

APPROACH

The model was developed through a synthesis of data from a number of past tests. Tests impacting directly on development of the model were selected on the basis of the availability of comparative data, where the characteristic of comparison (e.g., one mine size versus another, or search mode of open hatch versus closed hatch) was varied systematically while other test conditions were held constant. Data from non-comparative test designs were used in some instances to verify the applicability of the model.

BASIC COMPARISONS

Mine Size

A test conducted by the Visual Detection Center at Picatinny Arsenal in 1970 provides data for a basic detectability comparison among different sizes of mines. It was concluded from a carefully designed and controlled test, "Other than volume, height is the most critical dimension. Any item with a large vertical dimension, such as the upright cylinder, is easily detected" (3). With scatterable mines of approximately equal volume, the key to detection would be the distance from the ground to the highest point of the mine as it happened to come to rest on the ground. In the remainder of this report the term "height" refers to that distance.

The Picatinny test resulted in detection distance for various sizes and shapes of objects placed on a flat, grass-free field in the Canal Zone. Among the objects were two cylinders. One was 2.5 inches in height and the other was 5 inches in height, both heights approximating those of mines now in use. Data from the report are graphed in Figure 1 as points on curves that trace the probability of detecting the objects as a function of their distance from a soldier walking along the ground.

Although the curves resulting from the Picatinny test portray the probability of a soldier's detecting single mines, they agree strongly with probabilities of a tank driver's detecting and avoiding numerous mines emplaced in a field. For example, a 1972 test conducted by the Army Materiel Systems Analysis Activity (AMSAA) resulted in a .93 probability of detection and avoidance of 2½-inch-high mines while tanks operated in the open hatch mode (5). As shown in Table 3, this probability of .93 was derived from data in the AMSAA report by assuming a baseline chance proportion of mines encountered equal of 1/6 of the mines in the field (tank width of 3 meters/field width of 18 meters = 1/6). That point is plotted as the letter "A" in Figure 1, at a distance of 15 meters. The distance of 15 meters represents the midpoint of a search range of 10 to 20 meters, the general distance at which a tank driver searches for a mine in an avoidance situation. At that distance from a mine, a driver would have about 5 seconds to maneuver around the mine while traveling 6-9 miles per hour. So 15 meters is a reasonable point on the observer distance scale to plot the .93 probability obtained.

TABLE 3

Summary of Data in AMSAA TM 137

	A	B	B/6 = C	1 - A/C
	Reported Encounters	Total Mines Fielded	Chance Encounters	Probability of Detection and Avoidance
Open Hatch	27	2160	360	.93
Closed Hatch	85	1080	180	.53

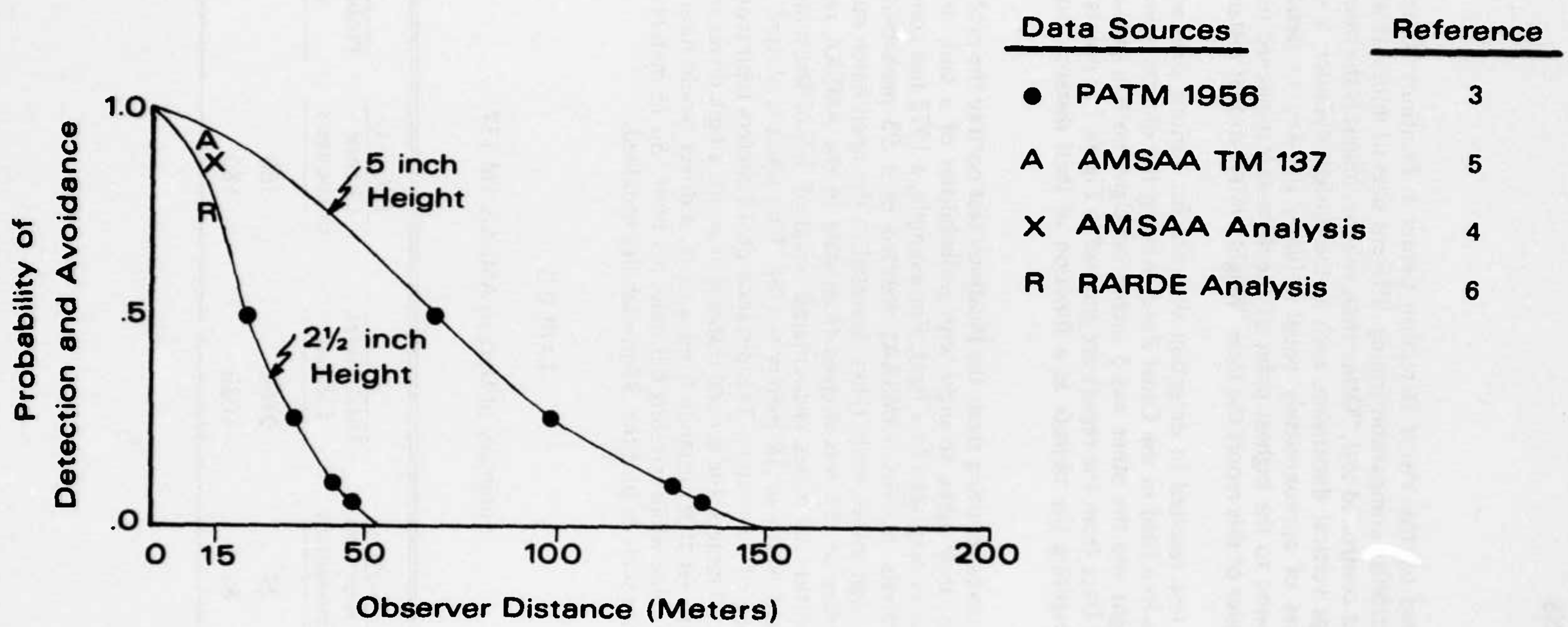

Figure 1. Probability of detection and avoidance of 2½ inch and 5 inch high mines, by observer distance.

As another example, the letter "X" in Figure 1 agrees strongly with the AMSAA point "A" and with the Picatinny curve for 2½-inch-high mines. Details of that agreement appear in a recent AMSAA report (4).

A third example came from a summary of data provided by the Royal Armament Research and Development Establishment (RARDE) (6). The RARDE analysis is extracted in Table 4 below, showing pairs of data reflecting differences in probabilities of detecting and avoiding mines for open versus closed hatch tank modes. Each of the pairs of data was collected under comparable circumstances of tank speed, type of terrain, and type of vegetation. A t-test for correlated means showed the mean probabilities of detection and avoidance for the open hatch and closed hatch modes (.68 and .40 respectively) to be significantly different from each other, statistically ($t = 5.23$, $df = 5$, $p < .01$). The open hatch mean value of .68 appears in Figure 1 as the point "R."

TABLE 4

RARDE Summary of Probability of Detection and Avoidance of Mines

	Open Hatch	Closed Hatch
	1.00	.71
	.47	.19
	.71	.30
	.95	.50
	.60	.47
	.35	.21
Means	.68	.40

The purpose for placing the data points of "A," "X," and "R" on Figure 1 is to show the general agreement among various tests as to the level of probability of detection and avoidance for the open hatch mode. Because of the general agreement among the tests, it is reasonable to say that the Picatinny Arsenal Curves are representative of differences in probabilities of detection and avoidance for mines of 2½ inches in height versus mines of 5 inches in height, for tanks driving in the open hatch mode through a flat, vegetation-free field of mines at a speed of approximately 6-9 mph.

Vegetation Height

It is not reasonable to assume that mines always will be placed upon terrain without vegetation during a conflict. Therefore it is necessary to provide a comparison for conditions in which the mines are obscured by some vegetation. In discussions with experienced tankers and test personnel, there was agreement that vegetation of one meter in height would obscure mines

to the near zero probability of detection. Figure 2 adds the dimension of vegetation height to the comparison made in Figure 1; the mine height curves on the probability X distance dimensions describe surfaces as they converge to a single vertical line at a vegetation height of one meter.

An opinion has been expressed by some persons experienced in the field of detection, and in some reports, that mines with a lower silhouette will approach a probability of detection of zero more rapidly than do higher mines, as vegetation increases from a height of zero to the height of the lower mine (12). Although the opinion has a high degree of face validity, there are no data available at this time to confirm such a hypothesis, or to characterize the nature of diminishing visibility gradients for various mine heights across varying vegetation heights. Therefore, Figure 2 incorporates a linear assumption (from zero to one meter vegetation height for both mines) to illustrate the general nature of the effect of vegetation height on probability of detection and avoidance.

Figure 3 illustrates the relationship of the two curves at vegetation heights of 0.25 and 0.50 meters. Figure 4 plots those two curves separately, with probabilities of detection and avoidance, and observer distance at their derived positions. As a check on the applicability of this geometric derivation, note the data point placed on Figure 4b. Mine effectiveness data (2.5 inch mine height) gathered in grass 10 to 24 inches (approximately 0.5 meter) in height during the Camp Drum test showed a probability of detection of .45 (2). When that probability of .45 is placed on Figure 4b at the 15 meter observer distance (the same distance used in Figure 1), it falls on the curve that represents the mine height of 2.5 inches, open hatch tank mode.

Figure 4a shows the relationship between the two mine heights for the 0.25 meter vegetation height, the type of vegetation that may be expected in a realistic situation. This graph of the open hatch comparison was used to derive closed hatch data.

Closed Hatch Versus Open Hatch

Table 3 and Table 4 of this report provide a means of transforming open hatch data to closed hatch data. The ratio of probabilities of detection and avoidance are nearly identical for both sets of data. Table 3 provides a factor of .57 = .53/.93, and Table 4 shows a factor of .59 = .40/.68 in going from open to closed hatch data. Because the test design and control procedures of the AMSAA test are known, and the circumstances of the RARDE data are not available at the time of this report writing, the factor of .57 was used in this analysis as shown in Table 5. Open hatch data in Table 5 are taken from Figure 4a.

TABLE 5

Comparison of Open and Closed Hatch Data

	Probability of Detection and Avoidance			
	Open Hatch	(.57) =	Closed Hatch	
Meters Vegetation Height	2.5 Inch Mine Height	5 Inch Mine Height	2.5 Inch Mine Height	5 Inch Mine Height
0.00	.80	.95	.46	.54
0.25	.63	.90	.36	.51
0.50	.45	.85	.26	.48

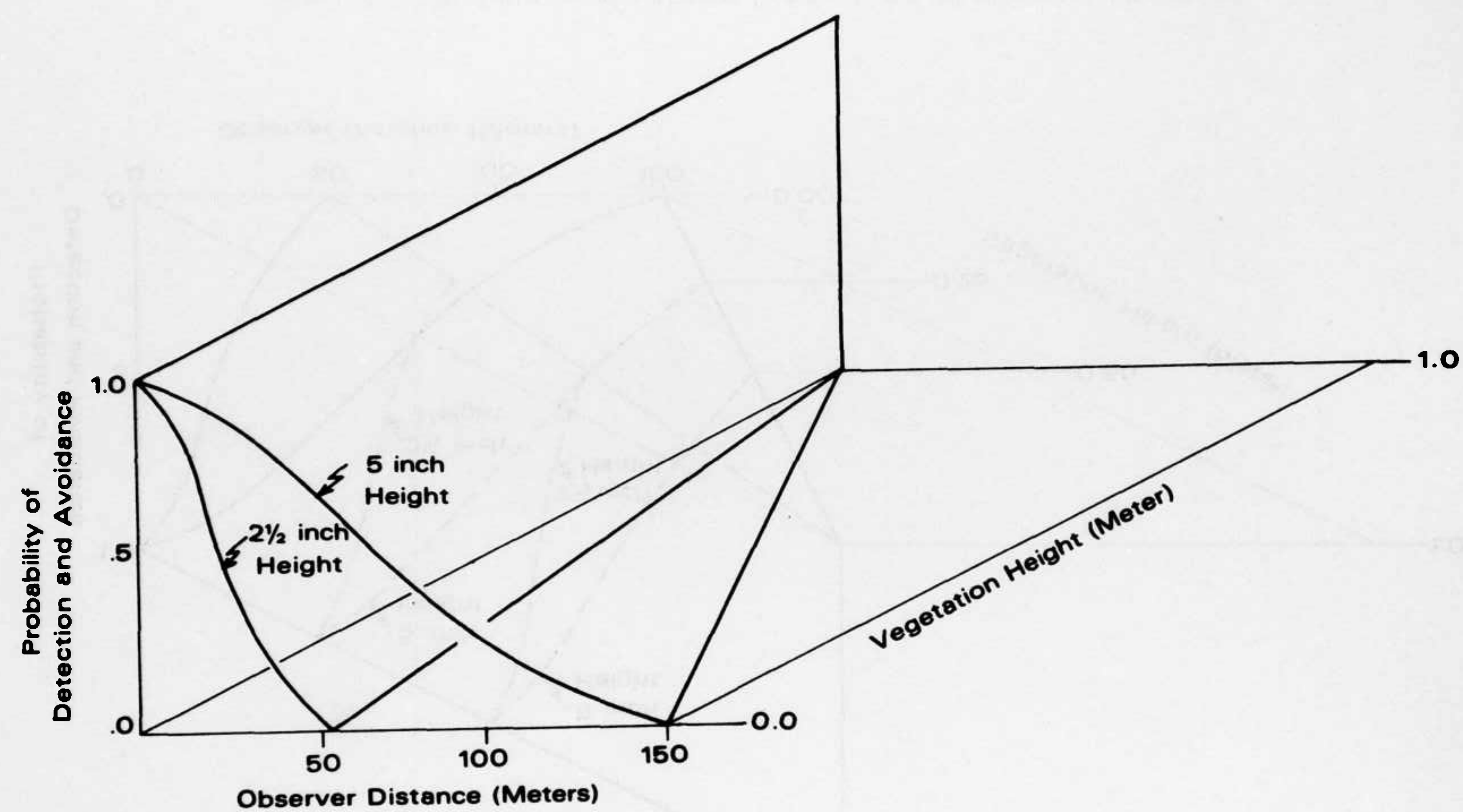

Figure 2. Probability of detection and avoidance of 2½ inch and 5 inch high mines, by observer distance and vegetation height.

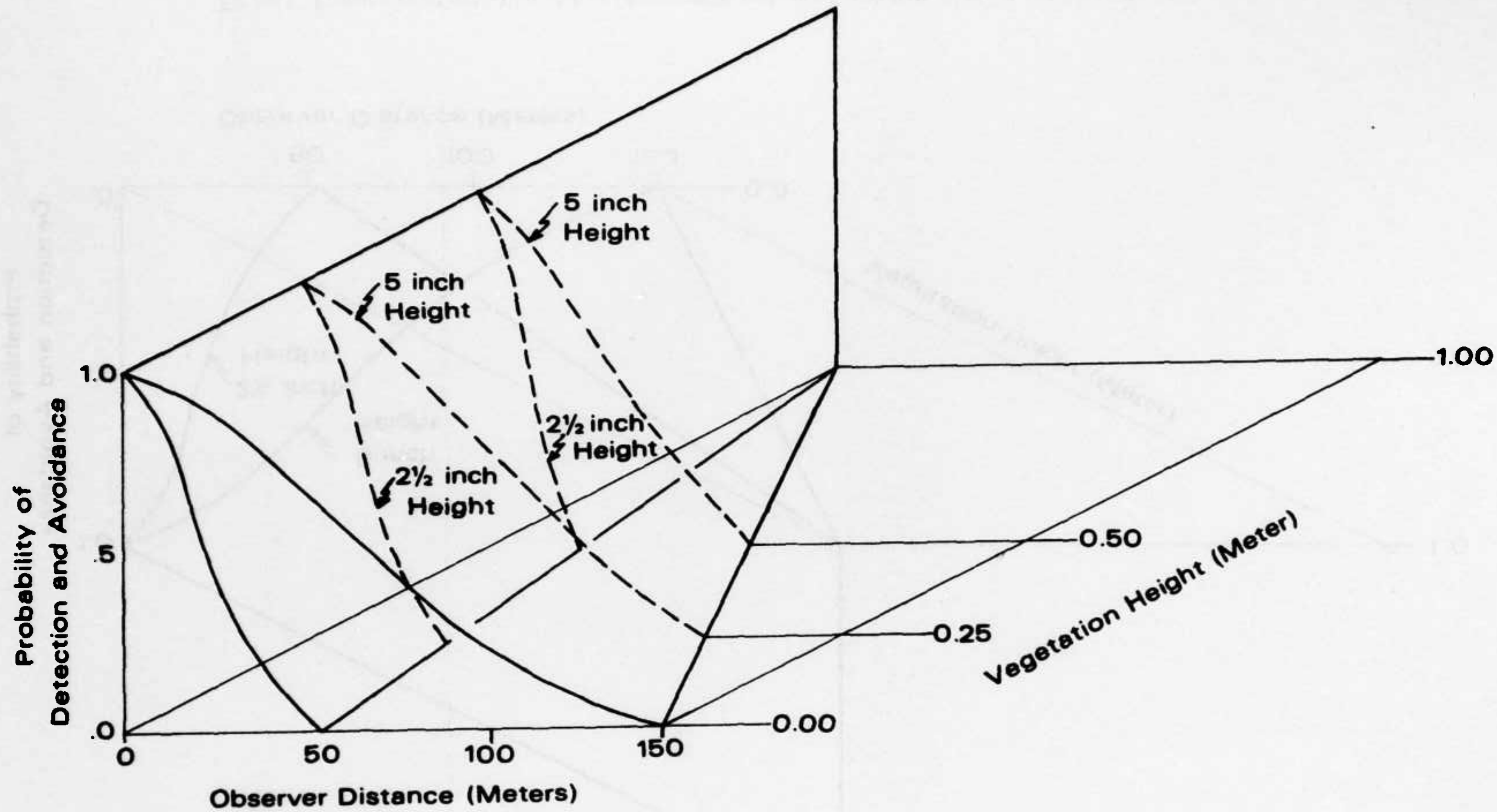

Figure 3. Probability of detection and avoidance of 2½ inch and 5 inch high mines expected at vegetation heights of .25 and .50 meters.

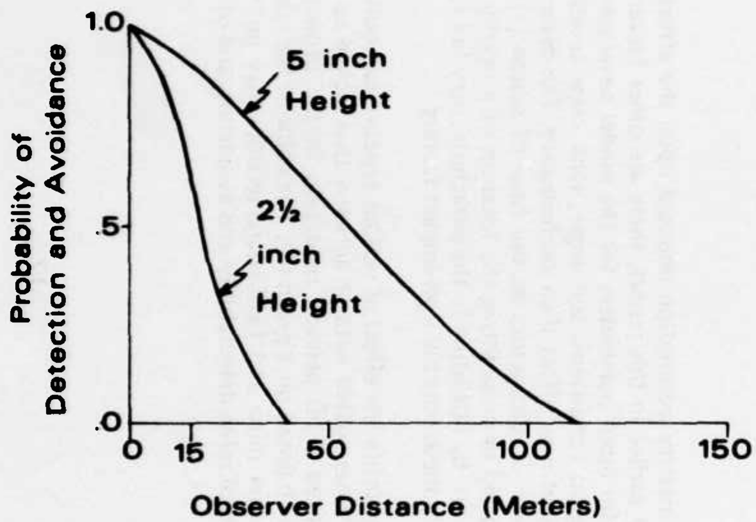

Figure 4a. Vegetation height of 0.25 meter.

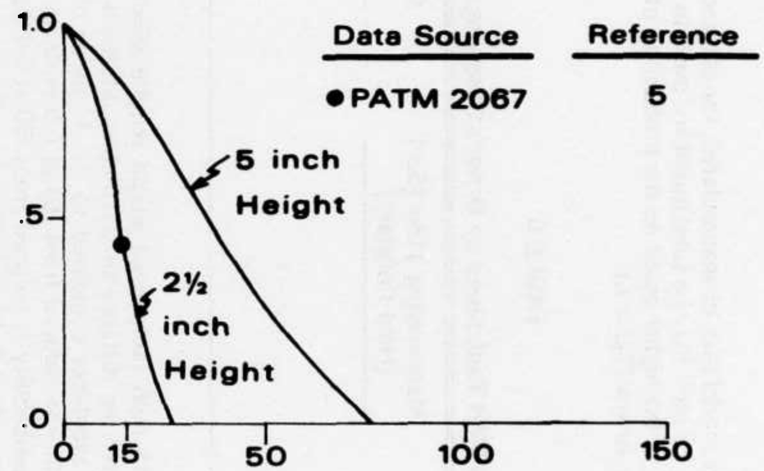

Figure 4b. Vegetation height of 0.50 meter.

Figure 4. Probability of detection and avoidance of 2½ inch and 5 inch high mines, open hatch mode.

Tank Speed

As an example of how the model may be manipulated, the parameter of tank speed may be altered. A tank speed of 10 to 15 mph may be substituted for the 6 to 9 mph used to devise the model (see page 5); the effect of the higher speed on the probability of detection and avoidance may then be estimated as shown below (Table 6).

TABLE 6

Effect of 10-15 MPH Tank Speed on Driver's Observing Distance

Tank Speed (MPH) (Independent Variable)		Maneuvering Time (Sec) (Held Constant)	Observing Distance (M) (Dependent Variable)
Range	Midpoint		
6-9	7.5	5	15
10-15	12.5	5	15 (12.5)/7.5 = 25

Table 6 shows that a 10-15 mph tank speed would require about a 25 meter observing distance. In Figure 4a, the observing distance of 25 meters intersects the two curves at lower probabilities of detection and avoidance compared to the 15 meter observer distance. For the 2.5-inch-high mine, the probability is reduced from .63 at 6-9 mph, to about .25 at 10-15 mph. For the 5-inch-high mine, the probability is reduced from .90 at 6-9 mph, to about .80 at 10-15 mph. These figures are for a vegetation height of .25 meter. Other vegetation heights and tank speeds would produce different probabilities.

Factors Not Considered

In addition to the linearity assumption imposed upon the effect of vegetation height on detectability as mentioned earlier in this report, there are other factors for which there are no data that may serve as useful input parameters for the model developed here. Among these are diurnal effects, meteorological conditions, sun angle, tank crew conditions of fatigue, hunger, sleep, or other distressors that may affect their performance. The detectability of an object may be changed by the presence of distractors in the field of search (1). For instance, a mine's parachute may serve as an aid in pinpointing the location of a nearby mine, or may serve as a distractor to an observer who, by attending to the parachute, may fail to detect the mine. Again, there are no data to quantify these possibly high impact factors.

There are data that quantify the effect of various types of camouflage on the proportion of mines detected in a field. Mines coated with an adhesive that picked up natural debris (grass and leaves) upon impact, achieved a 50 percent reduction in the proportion of mines detected compared to the same mines painted olive green (9). The color of the mine, it's camouflageability with natural debris, and other mine and field characteristics may be important parameters for specific tests or comparisons of mine detectability and avoidance, and of system effectiveness.

SUMMARY AND CONCLUSION

When comparing the effectiveness of scatterable antitank mine systems, the countermeasure of visual detection and avoidance is a significant aspect. The probability of detecting and avoiding antitank mines emplaced on the surface of the ground varies as a function of the height of the mine, the height of vegetation on the ground, the running mode of the tank (open versus closed hatch), and tank speed. Those four parameters were combined into a geometrically derived model to produce a point estimate of the probability of detecting and avoiding a mine system. Additional parameters needing investigation as possibly significant additions to the model are mine color, mine camouflageability with natural debris, the presence of parachutes or mine antennas, diurnal effects, sun angle, and psychological/physiological condition of the tank crew.

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